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The Washington Committee on the Relation of Electricity to Agriculture and Division of Agricultural Engineering Cooperating

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Grain Elevating Machinery for the Palouse Country

by

Harry L. Garver

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[1] In cooperation with the State Committee on the Relation of Electricity to Agriculture.
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FOREWORD

The Washington Committee on the Relation of Electricity to Agriculture and the State College of Washington are cooperating in studying the uses of electricity on the farm and in the farm home. The purpose at all times is to find ways and means whereby electric power may be used on the farms and in the homes of the state to the advantage of the farmer and his family at a cost which they can afford to pay and which will insure the continued availability of electric current in the open country.

The results of this work are published from time to time in the regular series of bulletins of the Washington Agricultural Experiment Station and in the general press and are brought directly to the people on the farm through the Extension Service of the State College.

This is the eighth of a series of bulletins dealing with the use of electricity on the farm. It is expected that other bulletins will follow.

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GRAIN ELEVATING MACHINERY FOR THE PALOUSE COUNTRY

By Harry L. Garver*

Introduction

With the reduction in prices of wheat (1931-32) has come a concerted effort on the part of growers everywhere to reduce the cost of production. Interest is rapidly developing in the handling of grain in bulk in the wheat-growing sections of the Pacific Northwest where, until recently, it was thought more satisfactory to handle it in sacks. Bulk handling in many instances has come to be considered as one of the means by which reductions of costs can be made, but neither the present type of machinery nor the storage facilities have been adapted generally to any other method than sacking.

The growers have already begun changing their machinery for bulk handling. This was not as difficult as had been expected. The disposition of loose grain is also a matter of concern. It must be taken from the harvester as soon as threshed, but few growers have storage on the farm, and most shippers have not yet erected bulk bins.

It was this situation that encouraged the Washington Committee on the Relation of Electricity to Agriculture to do what it could in helping to solve the problem. Cooperative projects with several growers were set up and some definite studies were made. The results of these studies are reported in this bulletin. Some suggestions are made which, it is hoped, will enable growers and shippers not only to reduce operating costs, but to select the kinds of machines best suited to their needs.

Certain kinds of elevators have had a reputation for cracking grain. Along with the cracking of grain the question of reduced germination naturally arises. Special attention has been paid to these two factors and their values reported.

KINDS OF ELEVATORS

There are three types of elevators in general use for handling grain on the farms of the Pacific Northwest, namely, the pneumatic or blower type, the bucket or cup type, and the flight or drag type.

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Two or three of each of these types were investigated. There is another type called the screw or spiral conveyor which is used mostly as a conveyor but frequently as an elevator. It is usually used in connection with some other machine such as a combine, separator, or grinder, and usually is operated as a part of that machine. For the sake of convenience the elevators studied will be referred to by number.

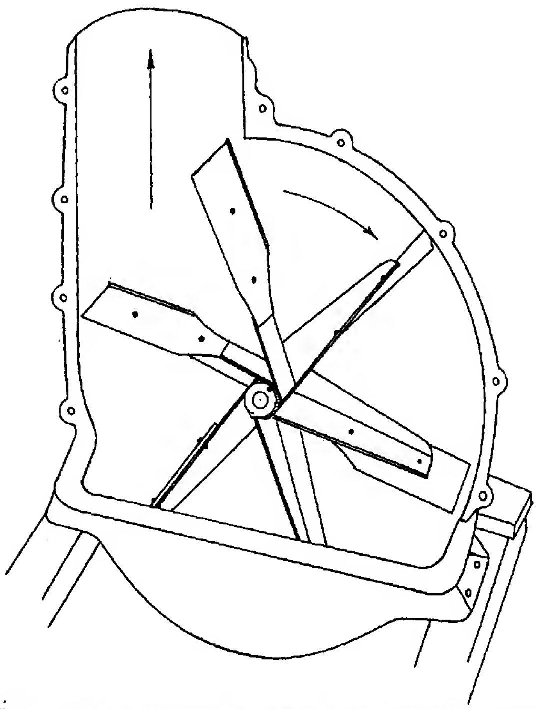

Figure 1. Diagram of fan showing flat blades. Note that the blades do not radiate from the center but slope slightly backward. Grain enters the fan from the near side. The blades of these fans have one edge turned slightly forward. This is the type of fan used in elevators Nos. 1 and 2.

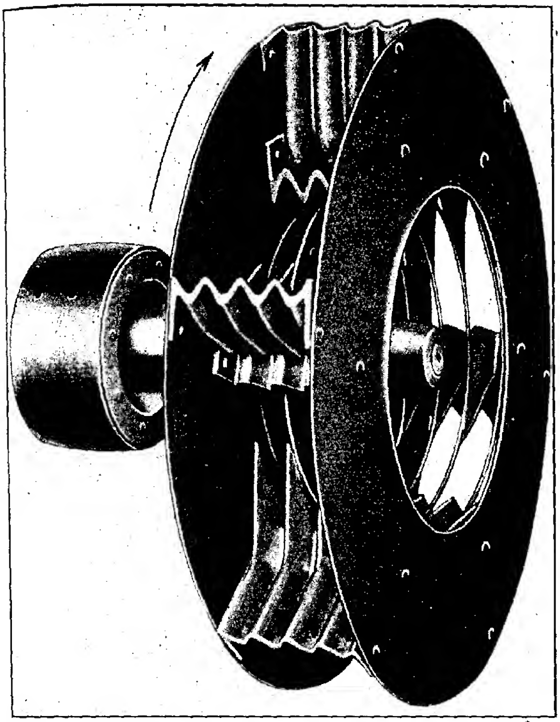

Figure 2. Runner used in elevator No. 3. Note the crescent shape and also the corrugated surface of the blades. The arrow indicates the direction of rotation.

Pneumatic Elevators

The pneumatic, or blower type of elevator, is just being introduced into the wheat growing sections of Washington. It has been used at terminal elevators and in mills for many years, but with the extension of electric service into the country this type of elevator is finding its way to the farms. It may be operated with any kind of power, provided the proper size of pulleys are used to give the correct speeds, but the comparatively high speed of the electric motor

and the ease with which it is started and stopped result in a desirable combination when a blower type of elevator and electric motor are used together.

Pneumatic elevators are made in three types: (1) Elevator in which grain passes through the fan, (2) elevator in which grain enters the air stream beyond the fan, (3) vacuum type. Only the first of these types was used in the studies herein reported.

Construction of Pneumatic Elevators. Elevator No. 1 consisted of a fan having six nearly radial blades. The heels of the blades were set forward slightly, thus giving the blades a backward slope. (Fig. 1.) A sheet-iron hopper with a screw feed was used in connection with this elevator. The screw was 5 inches in diameter with a pitch of 1.7 inches. It had only one bearing, which was located at the end opposite the fan. The other end was supported by the projecting end of the fan shaft, which also transmitted power for turning. The screw turned at the same speed (R.P.M.) as the fan.

Elevator No. 2 was the same as No. 1 except that it was operated without the screw feed.

Elevator No. 3 consisted of a six-blade runner operating in a steel case. The blades were made of cast steel. They were corrugated and curved slightly forward, somewhat like a volume type ventilation fan. (Fig. 2.) Heavy wires passed around the fan, being welded to the heel of the blades at the top of each ridge. These wires not only helped to strengthen the fan, but prevented large pieces of foreign material from going through and doing damage to the elevator. A sheetiron hopper fed the grain into the fan near the center. (Fig. 3.)

Each of the three elevators described was equipped with a sliding gate which could be raised or lowered to regulate the rate of feeding. The grain entered near the center of each fan and slid out along the surface of the blades. The manufacturers' purpose, apparently, in designing these fans so that the heel of the blades led was to give them a scooping rather than a batting action, hoping in this way to prevent cracking the grain. In none of the three elevators tested was the difficulty completely overcome, as may be seen by referring to Table 3. Theoretically, grain falling into the center of the fan was supposed to slide by centrifugal force out across the blades on a thin cushion of air without coming into actual contact with the metal. That this is probably not wholly true may be seen by examining the wear of the blades after a season or two of operation. The speed of the fans was from 785 to 1220 revolutions per minute.

The delivery pipes of all three of the blowers tested were essentially the same in that they were of steel tubing and butt jointed. A five-inch pipe was used on Nos. 1 and 2, and a six-inch on No. 3.

Nos. 1 and 2 were each fitted with a flexible joint and No. 3 with a 90 degree elbow, the outside half of which was of double thickness.

Two other types of pneumatic elevators are used in mills and elevators, but were not tested. In one of these the grain drops into the air stream beyond the fan, and is carried along wholly by the action of the moving air. (Fig. 4.) Reference to the manufacturers' recommendations for power requirements for given capacities would seem to indicate that these machines are less efficient than the elevators used in our tests. It is claimed that this type of elevator does not crack the grain.

The other type of pneumatic elevator is the vacuum machine. Vacuum elevators may be divided into two groups: (1) The grain passes through the fan. (2) The grain is separated out by means of a collector of some sort just before the air stream enters the fan. This latter type of machine is used mainly for unloading cars and boats, in which use its advantages are obvious.

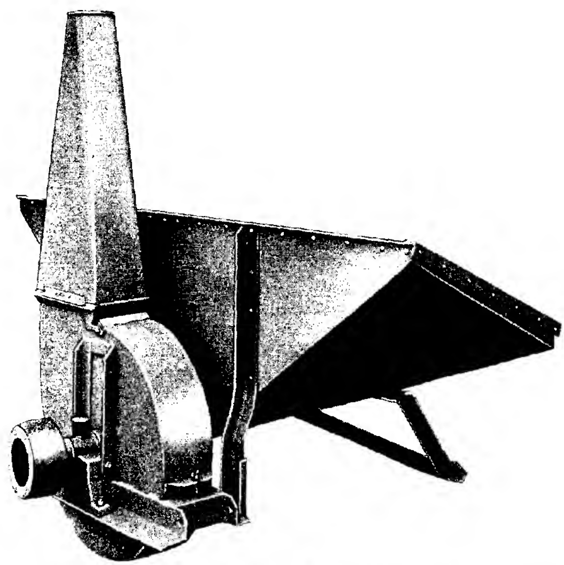

Figure 3. Pneumatic elevator assembled, showing truck type hopper in place. Note that this blower is welded together in places where replacements are not likely ever to be needed.

Operation of Pneumatic Elevators. The rate at which pneumatic elevators will handle grain depends upon the speed at which they are operated, and the amount of power available. A careful check made on elevator No. 1 while blowing 29 loads of wheat averaging slightly less than 30 bushels per load into a bin 20 feet high showed that an average of 7.8 minutes per load was required, which was an average of 3.5 bushels per minute, 210 bushels per hour. The fan turned at the rate of 960 R.P.M. (revolutions per minute). Twelve kilowatt hours of electrical energy were required to elevate 800 bushels to the top of a twenty-foot bin, which is a rate of 67 bushels per kilowatt hour. Figure 5 shows elevator No. 1 in operation.

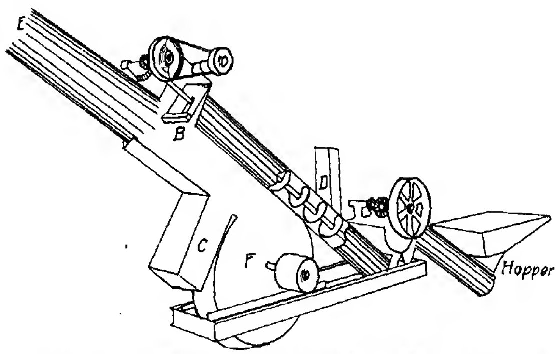

Figure 4. Pneumatic elevator. In this type of elevator the grain enters the air stream beyond the fan. When this fan is used as a booster for blowing grain to the ends of the car where the elevation is not great enough to shoot it there, the grain enters at "B" without going through the screw conveyors. When operating as shown, enough air passes back through the second screw to blow a large part of the dust out at "D." Heavy material drops into box "C." The fan is located at "F."

A test made on the same elevator when putting barley into a bin gave the following results. Approximately five minutes were required to blow 44 bushels into the bin through 10 feet of vertical and 15 feet of horizontal pipe, which was a rate of 530 bushels per hour. The average power requirement was nearly 5 Kw. which when converted to H.P., after taking into consideration the efficiency of the motor, is approximately 5. In other words, this outfit as used handled 106 bushels of barley per Kwh. of electric energy. ("A" Fig. 6.) Each vertical curve of the chart represents 2.5 minutes.

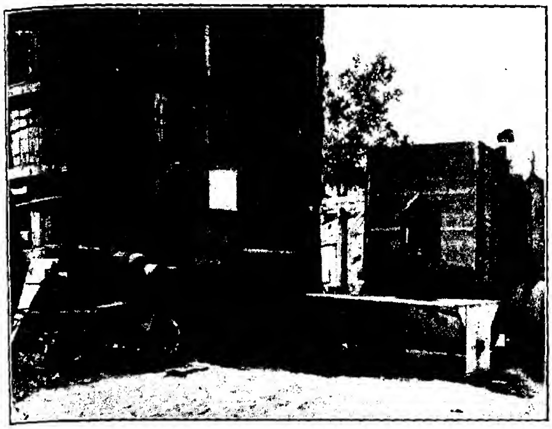

Figure 5. Pneumatic elevator blowing grain into a silo which is being pressed into service as a storage bin. A five H.P. portable electric motor is furnishing the necessary power.

Elevator No. 1 was also used to load from a storage bin at the railroad siding directly into cars. For this purpose the screw feed was removed and the grain allowed to flow from the bin into the hopper and thence to the fan by gravity. The blower was placed under the bin. A gate in the chute from the bin regulated the flow of grain into the elevator. Check was made on one 100,000-pound car which was loaded to capacity. This check showed the time required to be 6.25 hours. In other words, the elevator in this case handled 266 bushels of wheat per hour continuously. The energy consumption was approximately 25 Kwh. for loading the car.

Elevator No. 2 was operated without the screw feed. A three H.P. electric motor turned this elevator at 900 revolutions per minute. Wheat was elevated to a height of 20 feet at the rate of 2.9 bushels per minute, or 174 bushels per hour. The power required averaged about two Kw., the maximum being 2.4. From these data it is seen that 87 bushels were elevated 20 feet per Kwh. ("B" Fig. 6.)

A comparison of the power requirements for machines Nos. 1 and 2, when handling wheat at nearly the same number of bushels per hour, showed that nearly twice as much power was required when the screw was being used as when the grain entered the fan by

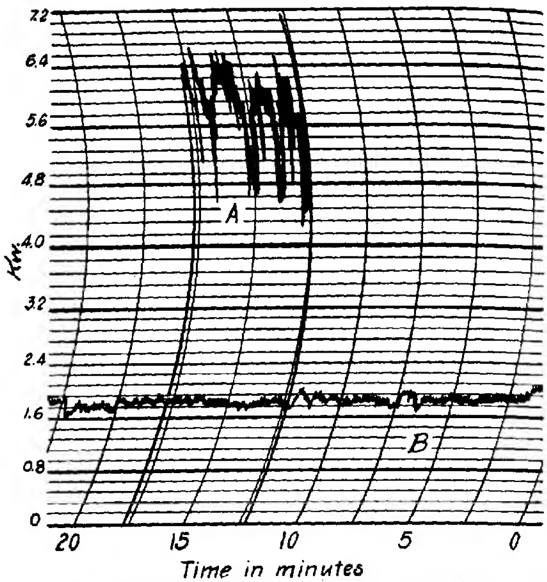

Figure 6. Power curves of pneumatic elevators. Curve "B" represents the power required to drive elevator No. 2 when handling 175 bushels of wheat per hour. Curve "A" represents the power required for unloading a 44 bushel truck-load of "Pearl" barley.

gravity. From this statement it would seem that it is much more economical to operate a blower without this type of screw feed than with it, especially when no provision is made to prevent the entire contents of the hopper from resting on the revolving screw. Another noticeable thing about operating the screw at this excessive speed was that the grain had a tendency to be batted by the flights, especially when the screw was only partially covered. Kernels of grain could be seen to fly forward from one turn and strike the turn ahead of it. This batting indicates that the screw was traveling much faster than was necessary or that the pitch was too great.

The third pneumatic elevator tested differed somewhat from Nos. 1 and 2 in that the blades, instead of being straight, were crescent shaped, the heel and toe both turned forward. These blades were made of cast alloy steel and had warped or corrugated surfaces.

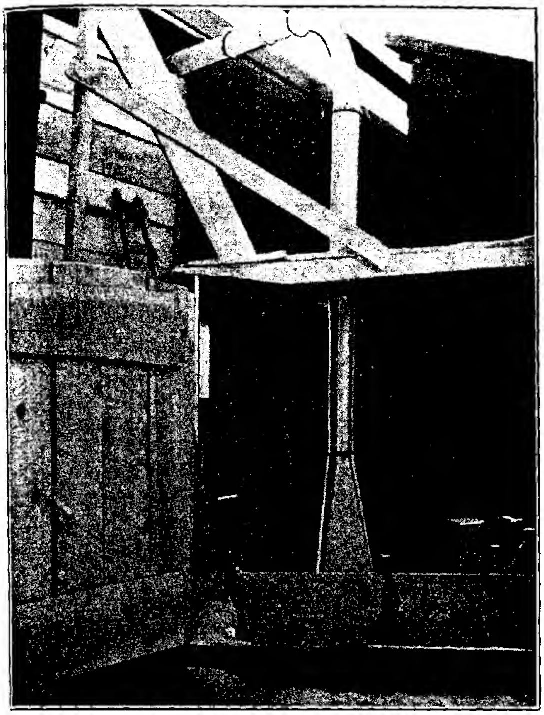

Figure 7. Pneumatic elevator being used to put grain into car at siding. The blower has been set down into a shallow pit. The discharge pipe swings from one side of the car door to the other. By turning the deflector hood grain may be blown to the ends of the car.

(Fig. 2.) That this type of runner was more efficient than the runner with straight flat blades may be seen from the data obtained. Figure 7 shows elevator No. 3 set up for loading from trucks directly into cars.

Careful check was made on one large carload. This was the ninth car loaded so that the machine was well worn in. The car was loaded with 122,965 pounds of Albit wheat. The actual operating time required was 193.5 minutes which was at the rate of 635 pounds per

minute, or 635 bushels per hour. The total time for loading the 61.5 tons of wheat, including waits between truck arrivals, was approximately 18 hours, which meant that the elevator operated about 18 per cent of the total time. The trucks that brought the grain from the combined harvester carried an average of 3510 pounds per load or nearly 60 bushels. The time required for the actual unloading of a truckload of this size was a trifle over 5.5 minutes. Some time was consumed in backing the trucks into position for dumping, bringing the total time trucks were held at the railway siding to about ten minutes. At this rate two grain trucks with specially equipped grain boxes were able to keep a 16-foot cut, tractor-drawn combined harvester going, even when the length of haul was as much as eight miles.

A record day's run with this outfit showed 1700 bushels of wheat harvested and hauled eight miles over a graded hard-surfaced road, and loaded into cars at the railroad siding, each truck traveling over 200 miles. One man stayed with the elevator, one with each truck, and two with the harvester, one driving the tractor and the other tending the separator and "punching" the header.

In all, 677.8 tons (22,670 bushels) of wheat were blown into cars with this elevator during the 1931 harvest. The blower was set in a pit about 12 inches deep, and raised the grain to a height equal to that of the top of the car doors, which was about nine feet. The grain was then carried horizontally a distance of six feet before entering the car doors. Here a deflector hood directed the grain to the ends of the cars. The rated speed of the fan was 1000 R.P.M. for small grain, but it was found that it could be operated nicely with a five H.P. electric motor on intermittent load such as this, provided it operated at slower speed. Accordingly a pulley combination was used which resulted in a fan speed of 785 R.P.M. Figure 8, "2" is a graphic record of the power required. Even at this speed the grain was thrown to the ends of the car, and by proper manipulation of the deflector hood was so placed that little or no trimming of the load was required.

Table 1 gives a summary of the cost of operating elevator No.3 during the 1931 harvest season.

Power Requirements of Pneumatic Elevators. Power requirements of pneumatic elevators are considerably higher than for either the flight or bucket elevators. Their initial costs are lower, however, which will probably compensate for the higher power requirement. In making tests, a five H.P. portable farm electric motor was used.

Versatility of Pneumatic Elevators. The pneumatic elevator, though less efficient from a mechanical viewpoint than other common types of elevators, is highly efficient from a utility viewpoint. It is readily

Table 1. Data on Car Loadings

Total truck trips	402.
Total weight of grain (tons)	677.8
Average truckload (lbs.)	3370.
Total number of cars	13.
Average carload (tons)	52.
Average grain handled per minute (lbs.)	635.
Average grain handled per hour (bu.)	635.
Time to load average car (operation hours)	2.75
Time required to load cars (average working hours)	18.5
Percentage of loading time elevator equipment operated	14.7
Speed of fan (R.P.M.)	785.
Power required (H.P.) (80% estimated motor efficiency)	6.0(max.)
Power used (electric motor) H.P.	5.
Total energy consumed (Kwh.)	208.
Kwh. per ton	0.307
Cost at 7 cents per Kwh. (for 677.8 tons)	$14.56
Labor at $3.00 per day (board included)	$72.00
Total cost per ton	$00.127*

* Does not include such charges as taxes, leases, depreciation, interest on investment, etc.

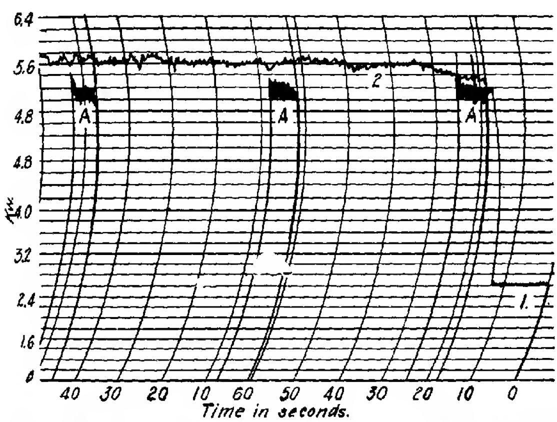

Figure 8. Power curve of elevater shown in elevator No. 3. Curves at "A" show the curves for unloading trucks proportionately spaced. The chart speed for these curves should be read in minutes, while that for observations on one load, shown at "2" should be read as indicated. The power required for running the fan empty is shown at "1."

portable and conveniently flexible. It may be used on practically all small grains and on shelled corn. From one position grain may be placed in bins or cars many feet away or close up with no other alterations than to add or remove a few joints of delivery pipe. This elevator will fill the bins to the top without the aid of a man and shovel, thus requiring no extra headroom for the job. While it lends itself nicely to use with an electric motor, it may be used with any kind of power, provided the speed is uniform, because excessive speeds are likely to crack the grain and the machine may choke on low speeds.

None of the three pneumatic elevators used in these tests were designed for lifting grain more than 30 feet. The practicability of lifting grain to a height of over 25 feet with a blower type of elevator has not been investigated by the Washington Experiment Station.

Flight Elevators

By the flight conveyor is meant the elevator which pushes the grain along a smooth trough or tube by means of flights or cleats attached to a belt or chain. In some machines the flights pass up through a closed tube, and in others an open, rectangular trough is used. If belting is used, part of the weight of the grain is carried on the belt itself, being held in place by the cross cleats which are attached to the belting. If link belts are used, the grain slides along the lower side of the trough as described above.

If steel tubing is used, circular flights may be made to a size that will just allow them to pass through the tube with no more friction than that caused by their weight. Figure 9 shows an elevator of this type being used for putting wheat into a bin in the barn. When so made the flights will not allow much grain to pass around them, and the elevator may be operated at a steeper angle than can be done with the open type of trough. It may be designed for gravity feed, but would be more convenient and portable when designed with a power feed attachment. This may be either a horizontal drag or a screw. In either case, provision should be made for preventing grain in the hopper from falling onto the drag or screw any faster than it can be handled by the elevator. (See discussion on screw elevators.) Portable elevators of the flight type for elevating up to 20 bushels per minute are now on the market.

Power Requirements of Flight Elevators. The power required for this type of elevator is from one-third to one-half that of the pneumatic elevator when handling the same amount of grain. Motors from two to three H.P. are usually sufficient. These elevators were designed for use with gas engines, and in most cases a jackshaft equipped with pulleys for reducing speed will be required if an electric motor is to be used with them.

Figure 10 is a portion of the record taken by the recording wattmeter on elevator No. 4. This elevator had stood out in the weather for several years, and was in rather poor mechanical condition. Even under these adverse circumstances, it elevated wheat from the ground through a window 18 feet above at the rate of 250 bushels per hour, and required only 1.4 Kw. input to the motor, which meant about 1.5 H.P. at the pulley. In the tests made on this elevator 486 bushels of wheat and 763 bushels of barley were elevated through a window 18 feet above the ground. The total electrical energy consumed was nine Kwh.

Figure 9. A flight elevator ready for putting wheat into the granary. A jackshaft was mounted on a short plank with the motor and switch making a unit of them.

Another elevator of the same make and model but one that had been kept in good condition required only two Kw. or about two H.P. at the driving pulley when elevating wheat to approximately the same height at the rate of 800 bushels per hour. Even here a large portion of the power required was used in overcoming motor losses and friction in the machinery. (Fig. 11.)

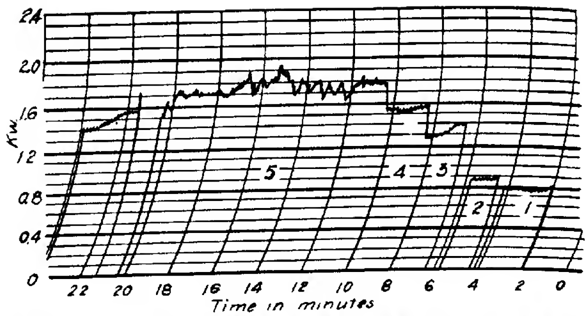

Figure 10. Power curves of the elevator shown in Fig. 9. "1" represents power required to run motor alone; "2" represents power required for motor and jackshaft; "3" represents power required to run all machinery except flights (empty); "4" represents power required to operate entire elevator empty; "5" represents power required to operate elevator when handling wheat at the rate of 250 bushels per hour.

The third flight type elevator (No. 6) tested used a rectangular wood pipe. (Fig. 12.) Tests were made only when barley was being elevated. The barley was raised about ten feet and dropped through the roof of the granary. The barley was handled at the rate of ten bushels per minute, or 600 bushels per hour. The actual maximum rate was considerably higher than ten bushels per minute, as the rate given includes the time taken for sweeping out the truckbox. The power required is shown in Figure 13. In all, 650 bushels of barley and 1200

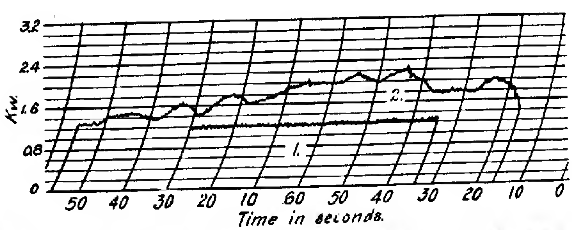

Figure 11. Power curve for elevator No. 5. The wavy form of this curve was probably due to the unevenness of feeding. A comparison of this curve with that shown in Fig. 10 will show some of the advantages of proper care of farm elevators. "1" Represents power required for operating elevator empty; "2" represents power required for operating elevator when handling 800 bushels of wheat per hour.

bushels of wheat were elevated, the total energy required being 11 Kwh. Figure 13 shows the amount of power required to operate this elevator.

All of the flight type elevators tested were driven by three H.P. electric motors.

Versatility of Flight Type Elevators. Practically all flight type elevators are designed with the hoppers in line with the elevator proper, which makes them convenient for dumping the grain from the truck box. A bridge can be built so that the truck may be driven over the hopper and dumped, except where the elevator must stand parallel with the granary, in which case the truck must be backed up to the hopper. The elevator shown in Figure 12 was equipped with a hopper that could be folded over the elevator tube and would thus allow the truck to drive through.

The flight elevator is not usually designed for shifting from one bin to another without moving the whole machine unless the bins are close together, in which case the drop spout may be shifted. Plenty of headroom must be provided because the upper end of the elevator

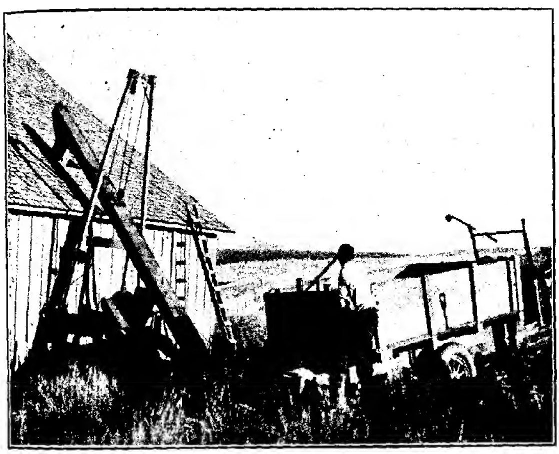

Figure 12. A flight elevator putting grain into an improvised granary in a barn. The hopper of this elevator will fold back against the tube, thus allowing the truck to drive straight through. Note that even though the front end of the truck was higher than the rear end by virtue of the slope of the land, a still greater slope was obtained by digging holes into which the rear wheels were placed.

must be considerably higher than the window through which the grain is dumped. This type of elevator does not lend itself to loading directly into cars as well as the blower or bucket elevator because it does not lift the grain to a sufficient height to cause the grain to shoot to the ends of the car.

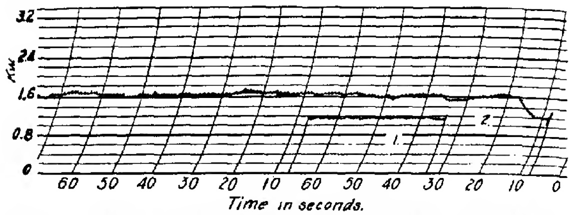

Figure 13. Power curve of elevator No. 6. Note the evenness of power demand in this elevator. Barley was being elevated at the rate of 600 bushels per hour.

Bucket Elevators

Bucket elevators have been in use in large grain elevators and in flour mills for many years. They have been used also on grain harvesters and threshing machines, corn shellers, and feed grinders, but as parts of these machines. A few farm granaries have also been equipped with them.

Construction of Bucket Elevator. Two bucket type elevators were investigated in making this study. Both of these were designed and built locally. Figure 14 illustrates in general how these elevators are made. Elevator No. 7 was approximately 45 feet between shafts; in other words, the elevator leg was about 40 feet in length. The cups were 10½" x 5" and spaced each 12 inches on a 12-inch belt. The cup speed was 380 feet per minute. A hopper with a capacity of nearly 100 bushels was constructed and a bridge built over it. The bridge was equipped with a large opening over the hopper so that, when the front end of the truck was raised and the gate at the back end of the box opened, the grain flowed into the hopper. (Fig. 15.) By using the large hopper it was possible for trucks to unload quickly and start back to the combined harvester. A hydraulic hoist was used in this case to lift the front end of the trucks.

Elevator No. 8 was a smaller outfit. The buckets were 7" x 5" and were spaced each 12 inches on an 8-inch belt. The pulley arrangement was such as to give the buckets a speed of 780 feet per minute. This speed would be too great for most elevators, but the head of this

elevator was comparatively large, and the buckets emptied satisfactorily. This elevator was 30 feet high. It was located about eight feet from the side of the car. Wood spouting was used to carry the grain most of the way from the elevator into the cars, just as was done with elevator No. 7. In both cases it was necessary for someone to shovel the grain back to the ends of the car.

A bridge was built from the highway to the hopper, but it was necessary for the trucks to back over the bridge to dump. A short

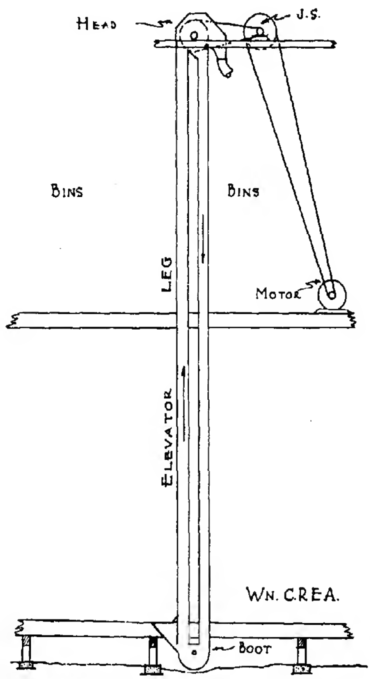

Figure 14. Diagram of elevator showing the various parts in their places. It is not necessary to place the motor on a floor below the level of the head of the elevator as shown here, but this position is frequently convenient in that the motor may be used for driving other machinery. "JS" represents the jackshaft which is used for reducing the speed of the motor to that required by the head shaft of the elevator. The hopper is shown in its proper position with respect to the boot. A large auxiliary hopper may be built over this to take care of truck loads of grain, as is shown in Figure 15.

section of the bridge was raised to give the truck sufficient slope to allow a considerable part of the load to flow out by gravity. (Fig. 16.)

In designing a bucket type elevator, several factors that must be considered are: (1) The capacity of the elevator, i.e., bushels per hour, (2) the speed at which it is to run, (3) the cubical contents of the buckets, and (4) the spacing of the buckets. When the proper shape of bucket is selected for a given speed and size of head pulley, it should fill to 65 or 70 per cent of its actual cubical capacity. Figure 17 shows a standard bucket. Since the conditions under which these elevators operate vary greatly, it is recommended that a competent millwright be consulted before building. Bucket elevators should stand near the car and be of considerable height to allow the grain to acquire the necessary velocity to reach the end of the car. Sixty feet above the top of the car door is considered sufficient for loading cars of 100,000 pounds capacity without having to use a scoop, except perhaps for trimming.

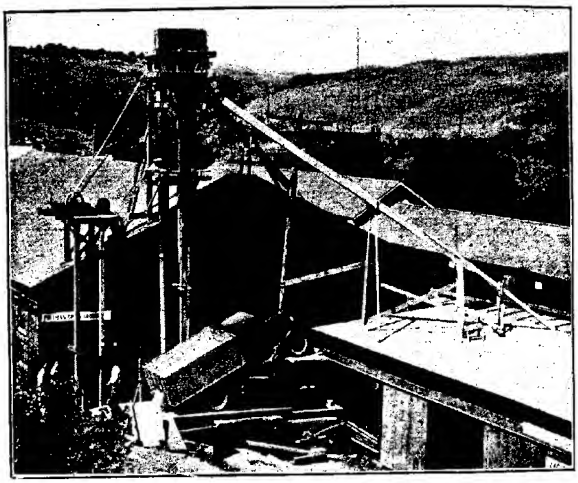

Figure 15. A bucket elevator in operation. Note the method of emptying the truck. The front end is lifted by means of a hydraulic hoist. The front wheels of this truck are about four feet higher than the rear wheels. Grain would not shoot to the ends of the car, because the elevator is too far from the tracks for its height. The motor stands at the left of the elevator and furnishes power through a long belt.

The question of whether chains instead of belts may be used, occasionally arises. Chains may be used. The belt has an advantage over chains in that it does not require lubrication. The belt does not often break in operation because wear of the belt can be seen and replacements made, but an elevator chain may break without warning and usually causes considerable jamming and a considerable loss of time and patience.

Power for operating the bucket elevators is delivered at the head. (Fig. 15.) In order to keep the elevator belt from slipping it must be tightened, just as any other belt would be, by separating the pulleys. This is sometimes done by raising the head pulley, but frequently it is difficult to accomplish because of other parts involved. Therefore it is usually best to take up the slack by lowering the boot pulley. The various parts of a bucket elevator are shown in the diagrammatic sketch, Figure 14. Figure 18 shows the head and boot in greater detail.

Operation of Bucket Elevators. The operation of bucket elevators, like that of the other elevators discussed, is very simple. The maximum of efficiency obtains over a small range of speed only, on account of proper filling and discharge of buckets. This is particularly true in the case of the centrifugal-discharge elevators such as were used in the investigations on grain elevators conducted during the last two seasons.

The following table shows the speeds generally accepted as the best for given diameters of head pulleys on centrifugal-discharge elevators.

Table 2. Speeds for Vertical Centrifugal-Discharge Elevators*

Diameter head pulley (inches)	18	20	24	30	36	40	48
Rev. per minute	46	42	40	39	36	35	32
Bucket speed feet per min.	215	220	250	300	340	360	400
Suggested size of bucket (inches)	3½x3	4½x3½	6x4	8x5	10½x5½	12x7	16x7
Suggested spacing (inches)	10	12	12	12	16	18	18
Capacity at sizes and spacing suggested (bu. per hr.)	93	140	312	791	1136	2295	3387

*Table taken from R. R. Howell and Company's Catalog E-30.

In tests made on elevator No. 7 it was found that a 100-bushel truck box could be completely emptied into the hopper in two minutes. No shoveling or sweeping was required. The time for elevating 5,895 pounds or nearly 100 bushels of wheat was 8.5 minutes, which was a rate of 694 bushels per hour. This rate was about the maximum for the elevator. The average rate of elevating was 650 bushels per hour. Time tests were also made on this elevator when it was handling oats. Twenty-eight minutes were required to elevate 15,140 pounds.

Power Requirements. The recording wattmeter was connected into the motor circuit of elevator No. 7 for a few truck loads of wheat and oats. Figure 19 shows a portion of the chart. Examination of the chart will show that more than half of the power required for operating this elevator was consumed in motor losses, belt losses, and friction in the machinery. The sawtooth appearance of the curve is due to the use of two weights of belting in the elevator.

Elevator No. 8 was driven by a three H.P. gasoline engine. No carefully checked tests were made on power requirements. The average rate of elevating wheat was 424 bushels per hour.

The bucket elevator will raise grain to a given height requiring about the same amount of energy as the drag or flight elevator. Since but one of the bucket elevators investigated was driven by electric power, check was made on that one only. A five H.P. 1200 R.P.M. motor was used, but a glance at Figure 19 will show clearly that three H.P. would have been plenty. A watthour meter used in the tests showed that 0.138 Kwh. were required per ton of wheat and 0.14 Kwh. per ton of oats.

The speed of these elevators is comparatively low, the drive shaft usually turning somewhere between 30 and 40 R.P.M., which means that a jack shaft must be used for reducing the speed from that of the electric motor to that of the head shaft of the elevator. The electric motor is highly desirable for operating the bucket elevator because it maintains a constant speed and is easily started and stopped.

The following simple formula for determining the power necessary to operate a bucket elevator will be of assistance to one who plans to build one:

$$\frac{W \times H}{12000} = \text{horse power*}$$

where W is the weight in pounds moved per minute, and H is the height to which it is raised. This formula allows approximately 150 per cent for friction in machinery and other power losses.

* From Mark's Mechanical Engineers' Handbook. 1916 (Modified).

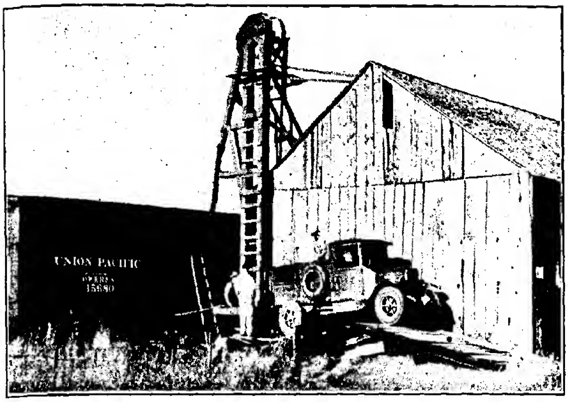

Figure 16. A small bucket elevator loading grain into the car. Note the method of constructing bridge to give slope to the truck box. The slope in this case is not sufficient to cause all of the grain to flow out. Power is transmitted through a long belt from an engine located in the building. It is seen that this elevator as well as that shown in Fig. 15 is standing near a warehouse which in the past was used to store sacked grain.

Screw or Spiral Conveyor

The screw or spiral conveyor is used quite commonly for moving grain horizontally, but is used occasionally for short elevations where the slope is not steep. The screw revolves in a box of steel, wood, or cast iron. (Fig. 20.) Wooden boxes are frequently lined with sheet iron or a light steel plate formed to fit around the screw with just enough clearance to prevent dragging. Power is applied at either end through pulley, gear, or sprocket.

The power required is given by the following formula:

$$H.P. = \frac{W \times L^*}{25{,}000}$$

where W is the weight in pounds moved per minute, and L is the length of travel in feet.

Table 3 gives the speeds and capacities of several sizes of spiral or screw conveyors.

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* From Kent's Mechanical Engineers' Handbook, Tenth Edition.

Table 3. Speeds and Capacities of Screw Conveyors*

Diam. of screw, inches	3	4	5	6	7	8	9	10	12
Max. r.p.m.	200	200	190	180	175	175	170	165	165
Bu. per hour	27	58	140	195	280	585	730	965	1750

* Table from Mark's Mechanical Engineers' Handbook (1916).

The feed hopper for a spiral conveyor should be so designed as to prevent the weight of all the grain in the hopper from resting on the screw. Grain falling onto the screw faster than it can be carried away will be churned over and over, and will result in an unnecessary consumption of energy and also in some cracking.

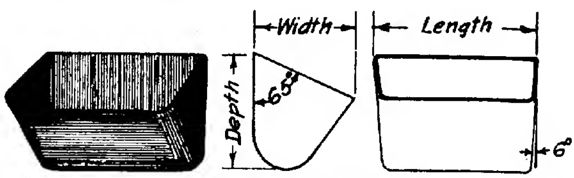

Figure 17. Detail of bucket used in bucket elevators. The form shown here is that of a "Manufacturers' Standard" bucket. There are several other forms of buckets, but this is the most common.

DEPRECIATION OF ELEVATORS

Elevators Nos. 1 and 2 have each been operated for two seasons, and No. 3 has been operated for one season. Elevator No. 1 has handled 44,062 bushels, while No. 2 has handled 21,800 bushels. The first two did not seem to impart as much speed to the grain as did elevator No. 3, which probably accounts for the fact that a 90 degree elbow in the delivery pipe of elevator No. 3 wore through more rapidly than the flexible elbows on the other machines. The elbow on No. 3 wore through after about 440 tons (14,666 bu.) had been blown through. While no new parts have been required for either of the other pneumatic elevators, there are very distinct evidences of wear in the flexible elbow of No. 1. The flat blades wear rather uniformly over the entire surface, but the greater part of the wear in the corrugated blades was at the bottoms of the valleys. After handling 23,860 bushels of wheat, the grooves worn in these valleys were from 15 to 20 per cent of the thickness of the blade. The width of the grooves was a little greater than the diameter of large kernels of wheat.

Observations on other types of elevators gave no indication of the length of life that may be expected of them. Some of the flight elevators have been in operation from six to eight seasons, but no record has been kept of the amount of grain handled.

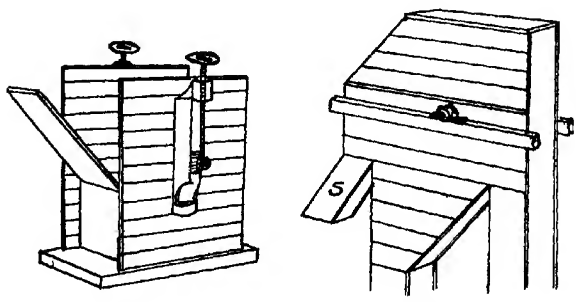

Figure 18. The head and boot of a bucket elevator. Note that the elevator belt is tightened by means of screws located on the bearings of the boot shaft. Grain feeds into the buckets as they leave the boot pulley. As the buckets pass over the head pulley the grain is thrown out by centrifugal action into the spout shown at "S." This spout may be extended to the bin or it may be made flexible so that it can be used to place grain in any one of several bins.

COSTS OF GRAIN ELEVATORS

The costs of elevators such as are discussed in this bulletin vary with the different types and with the different makes of the same type. The pneumatic elevator, although more expensive to operate, is least expensive to buy. The prices of machinery and equipment are likely to change, hence only the prices of the machines studied together with the place and year of purchase are given.

In discussing the cost of this equipment, the rate of depreciation should be included, but with the limited number of elevators studied and with none of them showing much evidence of wear, an estimate is impossible. Elevators Nos. 1 and 2 cost $150 delivered in Spokane in 1930. Elevator No. 3 with a truck type hopper was delivered in Spokane at $165 in 1931. The flight type elevator such as was used in the 1930 and 1931 tests sold in Spokane for $225 in 1931.

The cost of the bucket elevator will of course depend upon the height, the capacity, and the kind of material used in its construction. The costs of bucket elevators studied were approximately $450.00 for

No. 7 and $600.00 for No. 8. These costs included labor of installation, a three H.P. gasoline engine for No. 8, and a five H.P. 1200 R.P.M. electric motor for No. 7.

The operating cost of various types of elevators need not have much influence upon the type of elevator which should be installed for farm use. The energy consumptions as found by tests made during the 1931 harvest on the three types when handling wheat at approximately the same rate were as follows:

Flight	0.083 Kwh. per ton
Bucket	0.138 Kwh. per ton
Pneumatic	0.307 Kwh. per ton

At seven cents per Kwh.* it would cost $5.81 per 1000 tons with the flight elevator, $9.66 for the bucket elevator, and $21.49 for the pneumatic. At a three-cent rate, which would be the more common rate for farms using electricity for cooking, the costs would be $2.49, $4.41, and $9.21, respectively.

The foregoing operating costs include only electrical energy. The fact that no one is required in the car to shovel the grain back to the ends when using a blower may mean the saving of one man's time or at least an appreciable part of it. When this item is considered, it will probably be more economical to pay the larger power bill. If the bucket elevator is built high enough to shoot grain to the ends of a large car, much of the difference between the cost of energy for operating it and the pneumatic elevator will be eliminated. Flight type elevators are not generally sold in heights sufficient to shoot grain to the ends of cars.

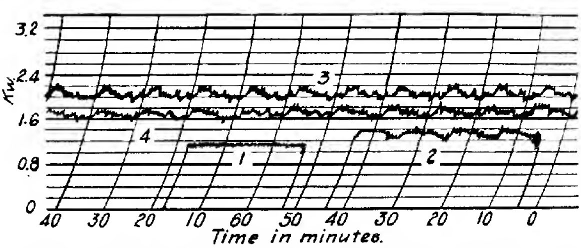

Figure 19. This is a power curve of bucket elevator shown in Fig. 15. "1" represents the power required to operate the motor when running idle; "2" the power consumed in operating the entire elevator without load; "3" power required for operating the elevator when elevating 650 bushels of wheat per hour; "4" power required for operating the elevator when handling oats at the rate of 850 bushels per hour.

* Commercial lighting rate (Fall 1931) of the Washington Water Power Company, operating in eastern Washington. This type of service being experimental with this company, no special rate has been assigned to it.

SUPPLEMENTAL EQUIPMENT

Much has been written recently on bulking attachments for the hillside type of combined harvester, and there is no need for repeating it here. Satisfactory truck boxes have been built also for hauling from the combine to the railroad or to temporary storage bins.

Present devices for dumping the grain from trucks into the hoppers of grain elevators are either inconvenient or expensive. The most convenient scheme permits the truck to be driven across the hopper without having to back up. Some device for raising the front end of the truck should be provided. Figures 15 and 16 show devices of this kind for emptying trucks. It is not usually convenient to use a bridge steep enough to cause all of the grain to run out of a truck box without adding some sort of hoist or tipping equipment. A 30 to 40 per cent slope should be sufficient, depending upon the shape and material of the box.

If the number of trucks is to be kept to a minimum, it is essential that they be emptied quickly. This can be done by the use of a large elevator hopper or by using an elevator with a large capacity. Large capacity elevators cost more to install than small ones and also cost more to operate.

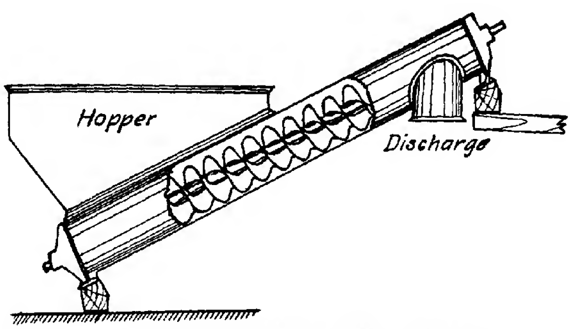

Figure 20. Diagram of a spiral or screw type conveyor. Note the simplicity with which grain is fed into and discharged from this type of elevator. The screw is not used to elevate grain to any great height, but is frequently found as auxiliary equipment on many kinds of machinery, particularly combines and threshing machines.

ADVANTAGES AND DISADVANTAGES

The advantages and disadvantages of the various methods of handling grain here given have been secured from two sesasons' observations on the part of the writer, and from the reports of grain growers who handle their grain in bulk.

Type of Elevator	Advantages	Disadvantages
Drag or flight	1. Low power requirement. 2. Hopper conveniently arranged for dumping from truck box, except when parallel with building. 3. Portable. 4. Especially suitable for loading trucks from bins or filling low grain tanks through the roofs. 5. May operate through a wide range of speeds.	1. Not flexible. 2. Length of tube not easily changed. 3. Too many sprockets and chains to get out of order. 4. Occupies considerable space. 5. Not suitable for elevating to high bins. 6. Does not work very satisfactorily at angles above 45°. 7. Capacities begin to drop when angle exceeds 30°.
Bucket	1. Low power requirement. 2. Adaptable to any height of bin. 3. Require very little floor space, as they lift the grain vertically or nearly so.	1. Comparatively high initial cost. 2. Not portable. 3. Works only within narrow range of speed for maximum efficiency. 4. Power applied at top of elevator. 5. If buckets are chain driven, no warning is given before a breakdown.
Pneumatic	1. Low initial cost. 2. Simple construction. 3. Flexible both as to height and direction. 4. Portable. 5. Occupies very little floor space. 6. Will work around corners. 7. Will load and trim cars without aid of scoop. 8. Aids in drying grain. 9. Loads cars evenly, thus insuring proper sampling and uniform grading.	1. Requires more power than bucket or flight type to operate. 2. Cracks some grain. 3. Limited height of elevation.
Screw or spiral	1. Compact. 2. Simple feed and discharge. 3. Can be completely enclosed to confine dust.	1. Uneconomical of power. 2. Limited to short lengths. 3. Will not work satisfactorily at steep inclines. 4. Blade easily damaged.

GENERAL OBSERVATIONS

When loading cars directly from the combine, as was done in the case of most of the elevators studied, there may be difficulties from car shortages. Difficulty from this source did not present itself during the time this study was made, probably because of the large number of grain cars available. A transfer bin may be located on the farm for use in case of a car shortage. In that case loading of the car may be done when no harvesting operations are in process.

Another handicap may be that of demurrage, should inclement weather or a breakdown occur with a car partly loaded. No cases of demurrage were reported during the seasons of 1930 and 1931. A review of one grower's operations may give an idea of what may occur. Everything was ready to go and the first truckload was delivered at the siding on July 30, 1931. On August 28 the last truckload was delivered. This was a total of 24 days omitting Sundays. Thirteen cars were loaded, an average of 1.85 days per car. Cars were set on the siding in the morning, allowing two full days for loading.

Another necessity in loading grain directly from the field into cars is the use of good sidings. They must be easily accessible with plenty of space for turning and dumping trucks, and the car should be so located that it need not be moved during the day.

In all of the tests conducted on loading bulk grain into cars, it seemed necessary to keep a man on the job to shift cars, sweep and line them, put in grain doors, seal and bill them out when loaded, see that empties were on hand, and do a multitude of other little odd jobs. Since these chores did not keep him busy, it would seem that several growers might cooperate and let one man look after these jobs for all of them. The pneumatic system lends itself to cooperative loading because two or more cars can be loaded from one location of the blower. It would not be necessary for any of them to lose the identity of their grain.

Although the drying of grain is not usually a requirement in the grain-growing sections of Washington, there are seasons when this practice may be advantageous. It is claimed for the pneumatic elevator that an efficient method of drying off some of the excess moisture is to circulate the grain through, drawing from the bottom of the bin and blowing into the top. This method is said to be particularly effective in cooling overheated grain.

Grain Cracking. Observations on the blower type of elevator soon showed that it was cracking considerable grain. The first question to arise was whether or not it would be sufficient to change the grade. Approximately 15,000 bushels of wheat went through two of the blowers twice with no change of grade. It would seem, therefore,

that with the present regulations there is little likelihood of grades being reduced as a result of cracked grain, especially in the soft wheats of Washington, Oregon, and Idaho.

Samples of wheat were taken as it came from the combine and again after it had gone through the elevator. These were taken at various times both morning and evening and at various times throughout the harvest season. Too few samples were taken to establish a correlation between the relative humidity of the atmosphere and the percentage of cracking, yet our data do show the effect of cutting and threshing damp, tough grain. (Nos. 11 and 12, Table 4.) This grain was harvested shortly after a rain and was still rather tough.

Whether cracking affects germination was another question asked. A series of tests were run on the samples collected, and it was found that with but a few exceptions there was a reduction in the percentage of germination with increased cracking. The germination tests were made on untreated grain about two months after it was harvested.

Table 4 was compiled from representative data collected during the harvest seasons of 1930 and 1931.

CONCLUSIONS

The power requirements of some types of elevators are much greater than for others, yet the cost of energy for the operation of any of these outfits is so small compared with the cost of manual labor that it seems to be extravagant to do by hand that which can be done by machinery and by the small amount of electrical energy used for power.

The cracking of the grain has not resulted in changing the grade. The reduction in per cent germination was not positive enough to justify discrimination against the pneumatic elevator in view of its other advantages.

There are no serious problems connected with the use of any of the grain elevators discussed in this bulletin. All have been used successfully. Each grower or dealer should study his requirements when contemplating the installation of an elevator or conveyor, and should buy the type most suited to his needs. A careful study of the chart showing advantages and disadvantages should be helpful in selecting the proper type.

An important factor in loading grain directly from the field into cars is the use of good sidings. They must be easily accessible, with plenty of space for turning and dumping trucks. The car should be so located that it need not be moved during the day.

Table 4. Percentage of Wheat Cracked in Passing Through Pneumatic Elevators, and Effect on Germination

Test No.	Blade Shape	R.P.M.	Variety	Date	% Cracked (a) Before	% Cracked (a) After	% Germination (b) Before	% Germination (b) After
1	Flat	960	Mosida	8/20/31	3.42	8.22	90.0	85.0
2	Curved	785	Albit	8/21/31	2.35	2.56	92.0	95.0
3	Curved	785	Albit	8/22/31	2.29	3.64	94.5	94.0
4	Flat	960	Mosida	8/24/31	3.90	5.07	81.0	74.5
5	Flat	960	Mosida	8/24/31	5.65	6.08	79.0	77.0
6	Curved	785	Federation	8/29/31	2.00	2.21	93.5	91.0
7	Curved	785	Federation	8/31/31	3.65	5.90	88.0	83.0
8	Curved	1220	Federation	9/ 1/31	2.35	4.63	90.5	84.0 (c)
9	Curved	870	Federation	9/ 1/31	2.00	3.42	93.5	91.5 (c)
10	Curved	870	Federation	9/ 2/31	4.16	7.00	90.0	93.0
11	Flat	—(d)	Albit	9/11/31	0.20	0.61	95.0	92.5
12	Flat	—(d)	Albit	9/11/31	0.23	0.40	99.0	93.5
13	Flat	875	Albit	1930	1.14	2.59 (1) 7.52 (2)	92.5	86.0 74.5

(a) The percentage of cracked grain was determined by the federal grain inspectors in Spokane.
(b) The percentage of germination was determined by the Farm Crops Division of the Washington Experiment Station. As much as 6 per cent variation existed in some of the samples tested for germination. Averages are given.
(c) Grain passed through cleaner.
(d) Speed varied. (1) First time through blower. (2) Second time through blower.

The grower who is contemplating the handling of his own grain in bulk should investigate not only each of the foregoing factors before purchasing his equipment, but also he should assure himself of a market or storage at harvest time and purchase equipment upon which he may depend for continuous operation so that delays may be avoided.

ACKNOWLEDGEMENTS

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Acknowledgement is also made to E. G. Schafer, Farm Crops Division, and L. J. Smith, Agricultural Engineering Division, for their helpful suggestions both in carrying on the tests and in preparation of the manuscript, and to the Standard Steel Works, North Kansas City, Mo., for some of the illustrations.

The General Electric Company furnished the motors and instruments for the tests. One pneumatic type elevator was furnished by Mitchell, Lewis and Staver Company of Spokane. The other elevators belonged to the farmers and dealers who cooperated with the writer in making the tests. George W. Hardgrove, Federal Grain Inspector, made the determinations in percentages of cracked grain.